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TITLE: TRAC PF1/MOD1 CALCULATIONS AND DATA COMPARISONS FOR MIST FEED AN BLEED AND STEAM GENERATOR TUBE RUPTURE EXPERIMENTS

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TRAC PF1/MOD1 CALCULATIONS AND DATA COMPARISONS FOR MIST FEED AND BLEED AND STEAM GENERATOR TUBE RUPTURE EXPERIMENTS*

by

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ABSTRACT

Los Alamos National Laboratory is a participant in the Integral System Test (IST) program initiated in June 1983 for the purpose of providing integral system test data on specific issues/phenomena relevant to post-small-break loss-of-coolant accidents, loss of feedwater and other transients in Babcock & Wilcox (B&W) plant designs. The Multi-Loop Integral System Test (MIST) facility is the largest single component in the IST program. MIST is a 2 x 4 [two hot legs and steam generators (SGs), four cold legs and reactor coolant pumps] representation of lowered-loop reactor systems of the B&W design. It is a full-height, full-pressure facility with 1/817 power and volume scaling. Two other integral experimental facilities are included in the IST program: test loops at the University of Maryland, College Park, and at SRI International (SRI-2). The objective of the IST tests is to generate high-quality experimental data to be used for assessing thermal-hydraulic safety computer codes. Efforts are under way at Los Alamos to assess TRAC-PF1/MOD1 against data from each of the IST facilities.

Calculations and data comparisons for TRAC-PF1/MOD1 assessment are presented for two transients run in the MIST facility. These are MIST Test 330302, a feed and bleed test with delayed high pressure injection; and Test 3404AA, an SG tube-rupture test with the affected SG isolated. Only MIST assessment results are presented in this paper.

The TRAC-PF1/MOD1 calculations completed to date for MIST tests are in reasonable agreement with the data from these tests. Reasonable agreement is defined as meaning that major trends are predicted correctly, although TRAC values are frequently outside the range of data uncertainty. We believe that correct conclusions will be reached if the code is used in similar applications despite minor code/model deficiencies.

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INTRODUCTION

Los Alamos National Laboratory has been involved with the Integral System Test program since 1984 and is currently performing code assessment of the Transient Reactor Analysis Code (TRAC) computer code against data from the Multi-Loop Integral System Test (MIST) facility. The MIST facility is a scale model of a Babcock & Wilcox (B&W) nuclear power plant. The facility is located in Alliance, Ohio, and is designed to experimentally investigate transients occurring after reactor trip and primary-pump coastdown. Data from the MIST facility are used to help resolve current plant licensing issues and also to assess and refine computer codes used to analyze plant thermal-hydraulic behavior.

A primary goal of our code assessment is to evaluate the adequacy of the correlations and models in TRAC. A related goal is to assist in developing an understanding of the phenomena occurring during the experiment. A secondary goal is to evaluate input modeling practices and develop user guidelines. In order to achieve these goals, it is necessary to understand the reasons for differences between test data and calculated values. These fall into three categories. First, a difference may exist because of an incomplete or inaccurate knowledge of the facility or its operation, including the instrumentation and the resulting data. Although this might seem to be a minor problem, it has not been for many facilities. Differences of this type may be difficult to isolate and can mask problems with the input model or the code. The documentation of the MIST facility, its operation, and data qualification are excellent, although there have been occasional problems as occur in any complex facility or test sequence. Second, the input model may be inadequate because of modeling compromises, noding, use of one-dimensional instead of three-dimensional models, etc. Third, inadequacies in the code closure models and correlations can cause differences. A major task of an analyst in code assessment calculations is to understand the differences between calculation and test within this framework, and in the case of code deficiencies, to identify the particular code model or correlation causing the difference.

Two assessment studies performed with TRAC-PF1/MOD1, version 14.3 (Ref. 1), are reported in this paper. Experimental data for MIST Tests 330302 (Refs. 2-3) and 3404AA (Refs. 4-5) are compared with code-calculated results. The complete TRAC posttest analysis of MIST Test 330302 is documented in Ref. 6.

Test 330302 was conducted to examine an extended period of pressure-operated relief-valve (PORV) actuation without makeup and with the steam generators (SGs) unavailable. In addition, high pressure injection (HPI) was delayed to permit extensive voiding in the primary system to occur. It was anticipated that the HPI, when finally actuated, would perturb system conditions because of condensation and depressurization.

Test 3404AA was one of a series of Steam Generator Tube Rupture (SGTR) tests performed in the MIST facility. A double-ended rupture of 10 SG tubes in the top of the B loop SG was simulated with the affected SG isolated when the primary pressure dropped to 6.55 MPa (950 psi).

CODE DESCRIPTION

The calculations reported herein were performed with TRAC-PF1/MOD1, version 14.3, with a MIST-specific update. The TRAC-PF1/MOD1 code (Ref. 1) was developed at Los Alamos National Laboratory to provide best-estimate predictions of postulated accidents in light water reactors. The code features a two-phase, two-fluid nonequilibrium hydrodynamics model with a noncondensable gas field; flow-regime-dependent constitutive equation treatment; either one- or three-dimensional treatment of the reactor vessel; complete control-systems modeling capability; a turbine component model; and a generalized SG component model.

Code modifications were necessary for this application. We made changes in the TRAC-PF1/MOD1 code to improve the calculation of falling-film heat transfer on the secondary side of the SG tubes when the auxiliary feedwater (AFW) is active. The falling-film heat transfer from the AFW was calculated in the updated code version by redistributing the liquid in the single-channel secondary to the heat slabs connected to the three-tube primary channel. In addition to the liquid redistribution, a multiplier was applied to the Chen correlation heat-transfer coefficient for the wetted-channel heat slabs. These code changes resulted in a more accurate calculation of the heat-transfer distribution and the thermal-center elevation in the SGs. We note that the code update produced is specific to the MIST facility and not for general application.

TRAC MODEL OF MIST FACILITY

The TRAC-PF1/MOD1 input model of the MIST facility is constructed entirely of one-dimensional components. The model consists of 77 components that have been subdivided into 276 fluid cells. Figure 1 is a MIST facility arrangement drawing. Figures 2 and 3 provide an overview of the TRAC MIST facility model. The model was initially based on preliminary information provided in the MIST Facility Specification (Ref. 7). It has progressed to its present form as available as-built facility information was received from B&W. The model is considered to be rather finely noded and has been shown to predict the dominant phenomena during MIST experiments.

CALCULATION RESULTS

In this section we present and compare the TRAC-PF1/MOD1 calculated results with the measured and observed results for MIST Tests 330302 and 3404AA. We have attempted to develop an understanding of both the test and calculated results and will discuss these. The assessment descriptors appearing in Appendix A are used to characterize the degree of agreement between measured and calculated results.

Test 330302 Transient Calculation.

The test was begun from steady-state conditions meeting prescribed tolerances. A steady state calculation was run to 2000 s, corresponding to about five loop transits. At the end of the steady-state calculation, the primary and secondary system fluid conditions had stabilized within the uncertainties of the measured values.

Feed and bleed transient 330302 was initiated at time zero from the steady state by terminating all AFW to both SG secondaries. An overview of the resultant test and calculated transients is shown in Fig. 4.a–4.l. A summary of major events for Test 330302 is presented in Table I.

With the termination of AFW to the SG secondaries, the SG secondary inventory began to boil off. However, this process removed only part of the core energy and the primary system began to heat up and pressurize as shown in Fig. 4.a. In the test the primary pressurized to the PORV set point of 16.20 MPa (2350 psia) at 942 s. The same primary system pressurization

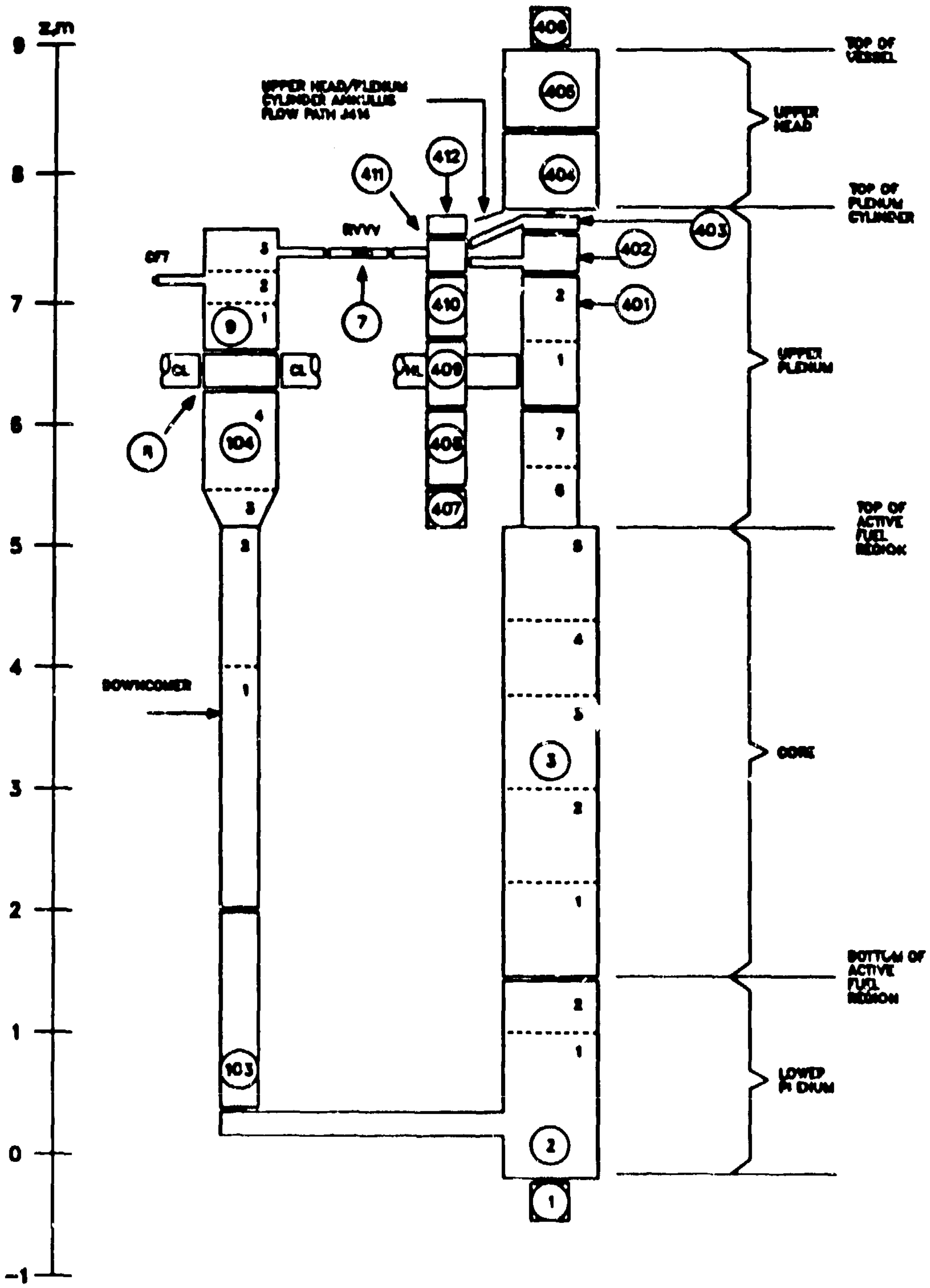

Fig. 1.
MIST facility isometric.

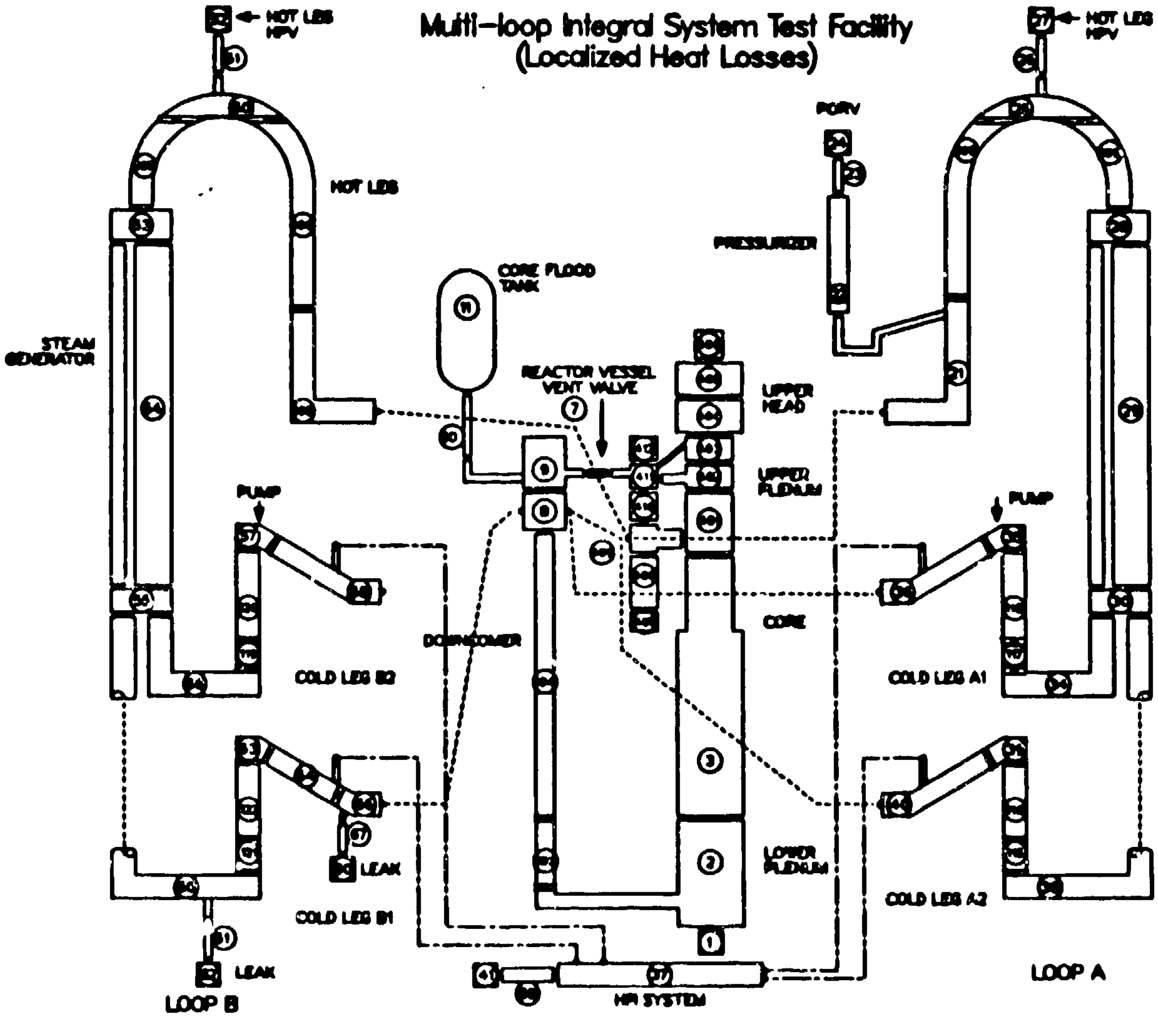

Fig. 2.
TRAC component noding schematic of MIST facility.

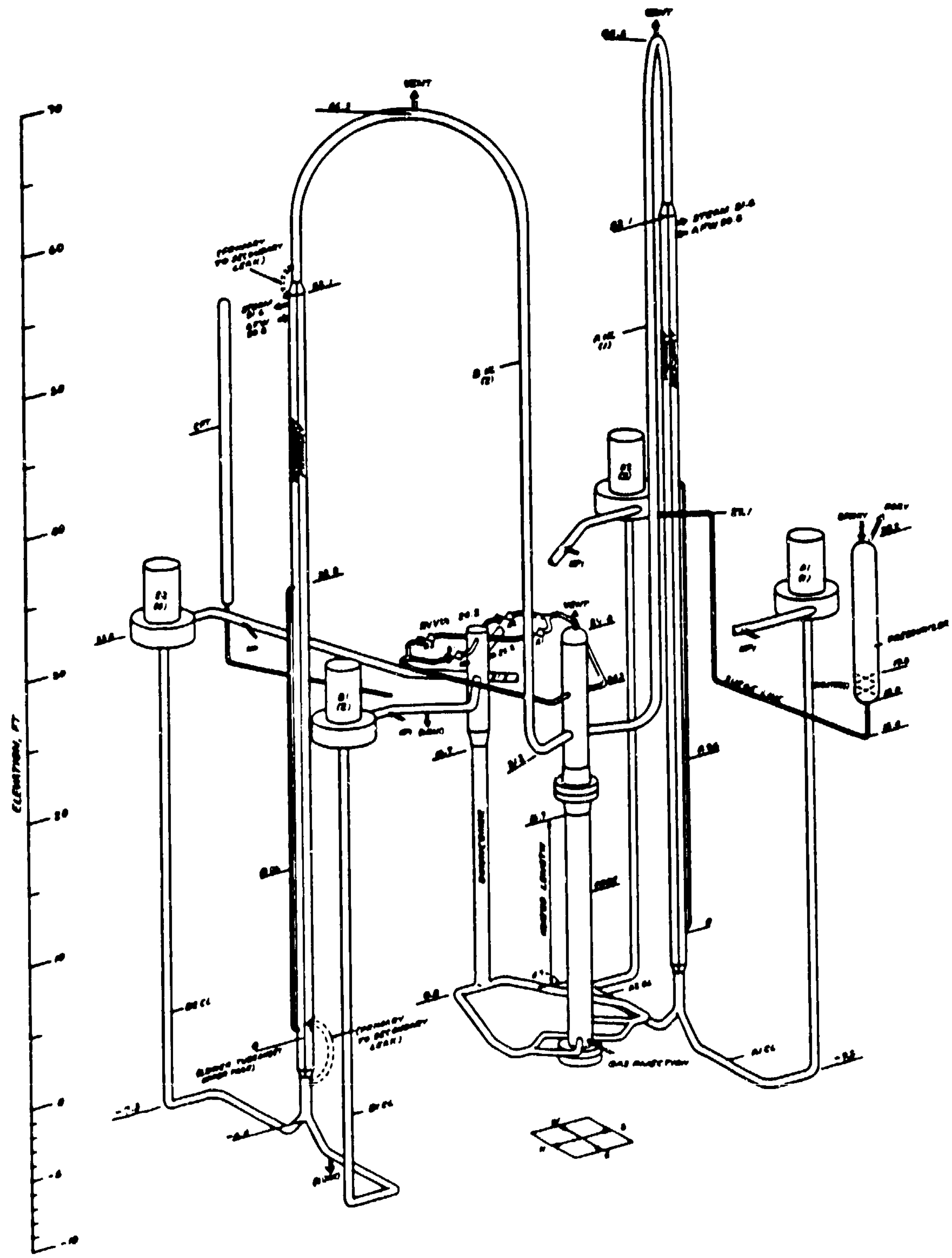

Fig. 3.
TRAC reactor vessel noding schematic of MIST facility.

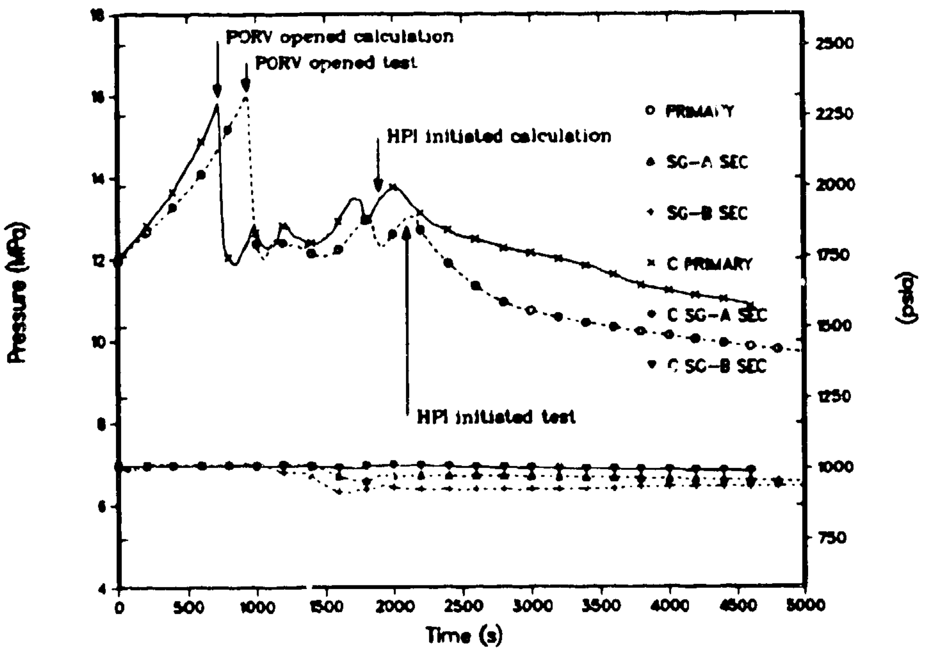

Fig. 4.a.
MIST Test 330302 primary and secondary pressure.

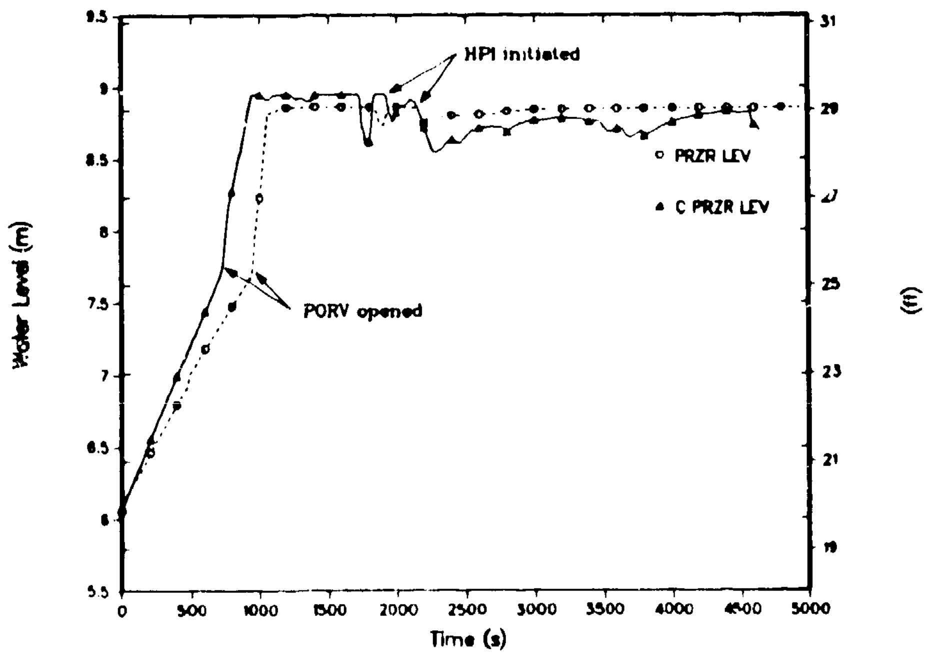

Fig. 4.b.
MIST Test 330302 pressurizer water level.

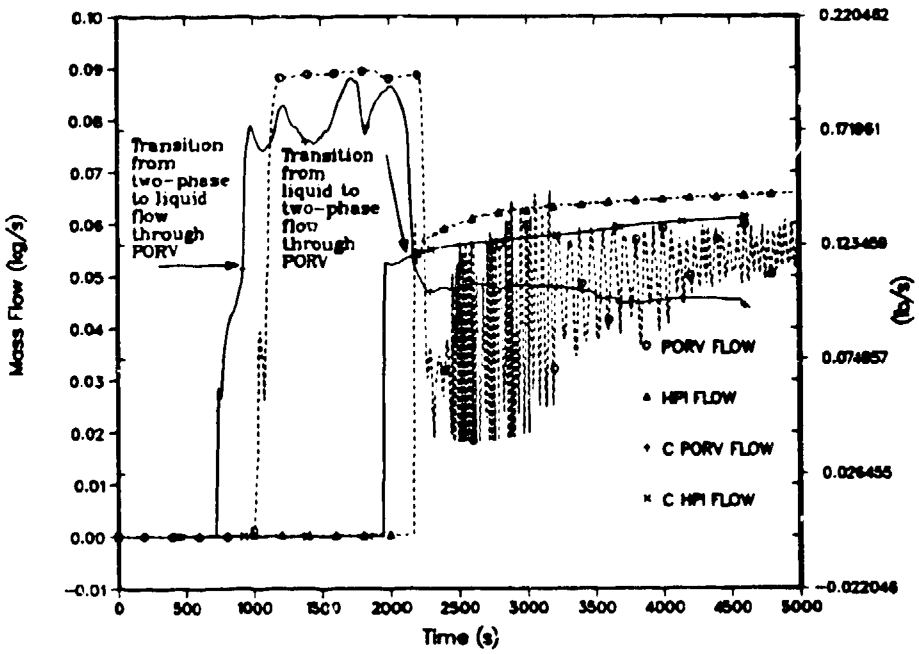

Fig. 4.c.
MIST Test 330302 PORV and HPI flows.

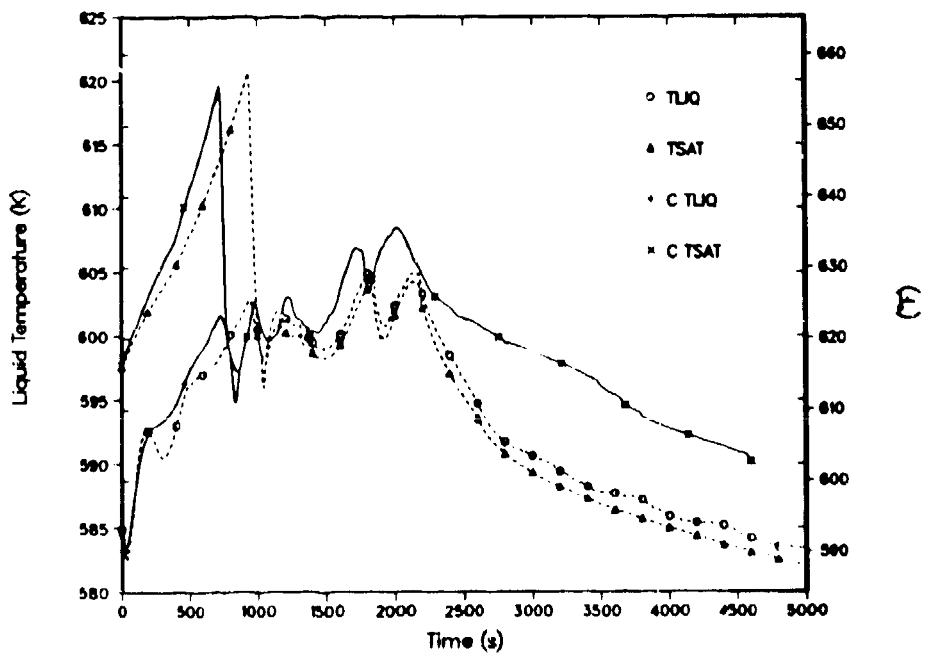

Fig. 4.d.
MIST Test 330302 core exit liquid temperature compared to saturation.

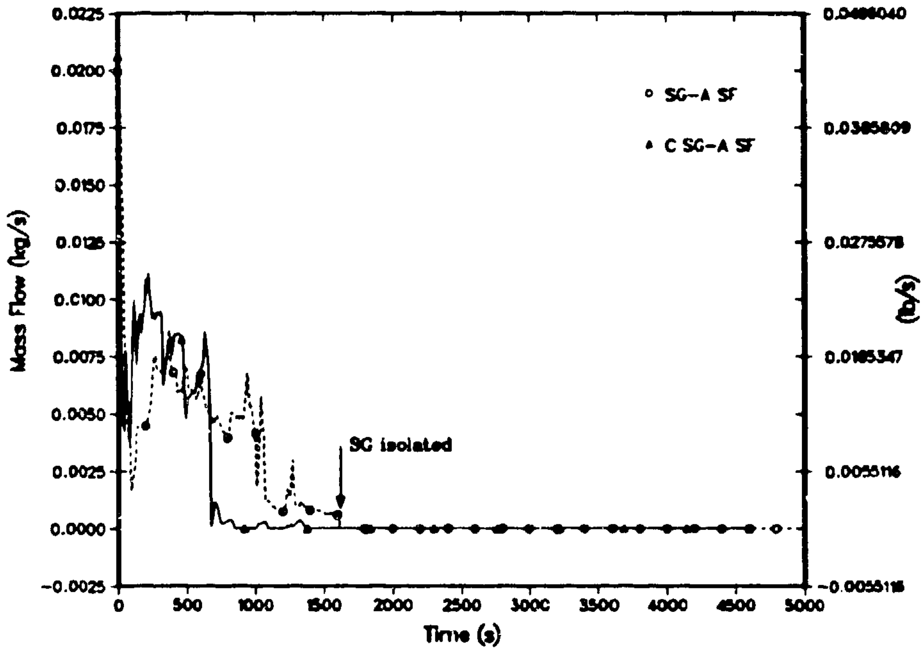

Fig. 4.e.
MIST Loop-A SG-secondary steam flow.

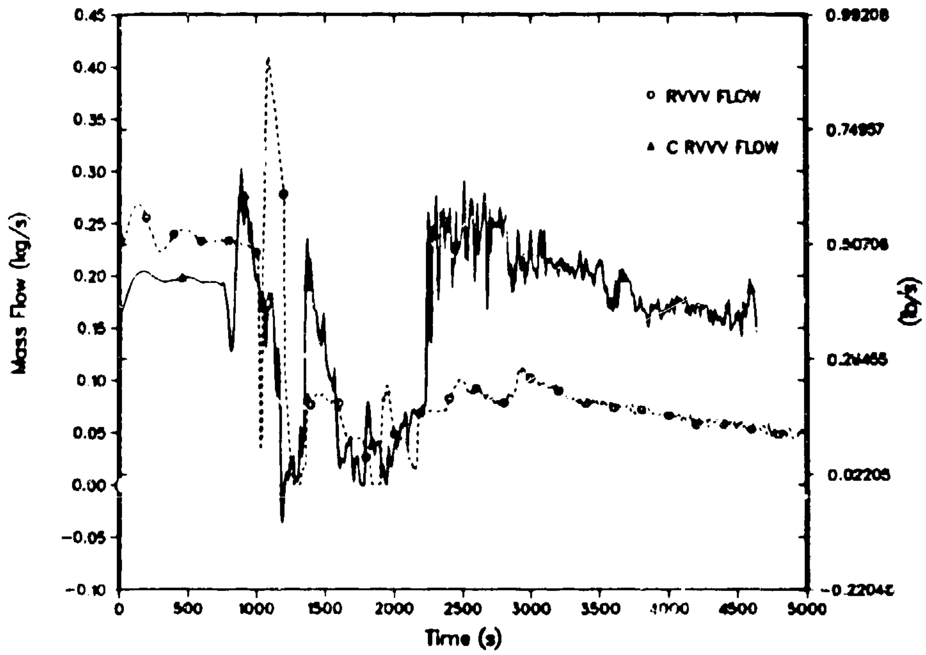

Fig. 4.f.
MIST Test 330302 reactor-vessel vent-valve flow (total of four valves).

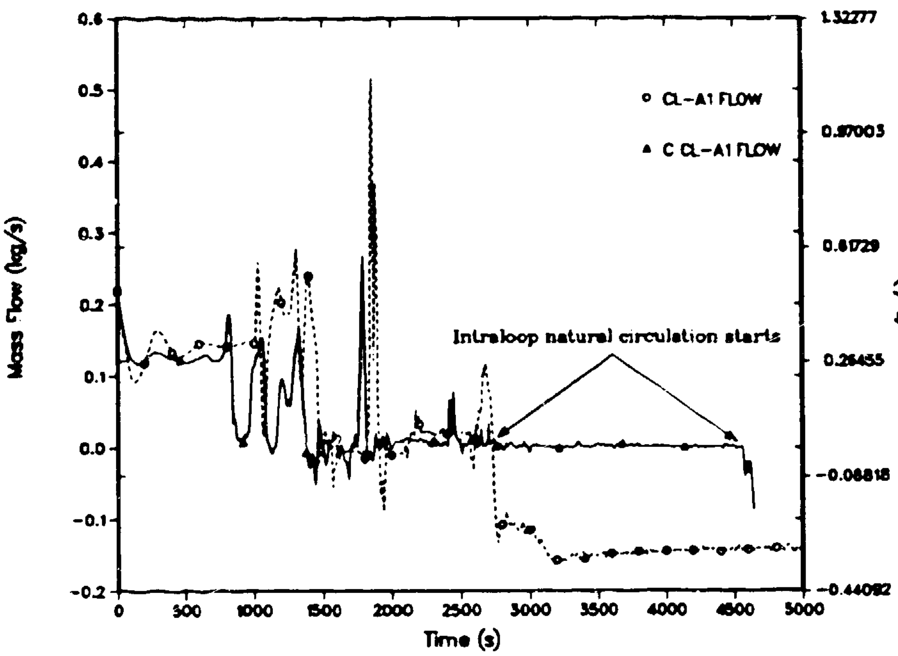

Fig. 4.g.
MIST Test 330302 Loop A1 cold-leg mass flow.

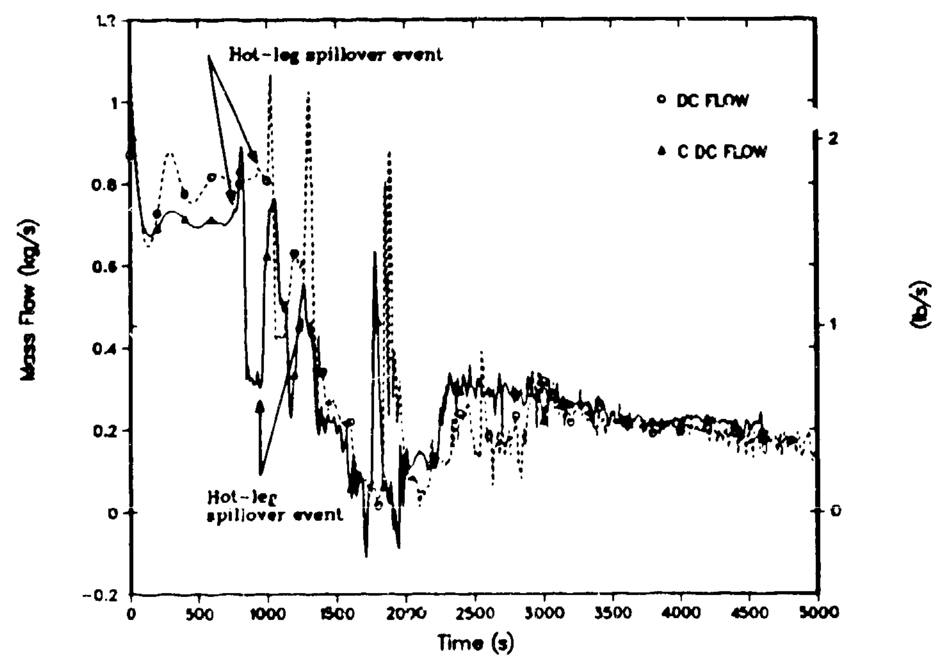

Fig. 4.h.
MIST Test 330302 downcomer mass flow.

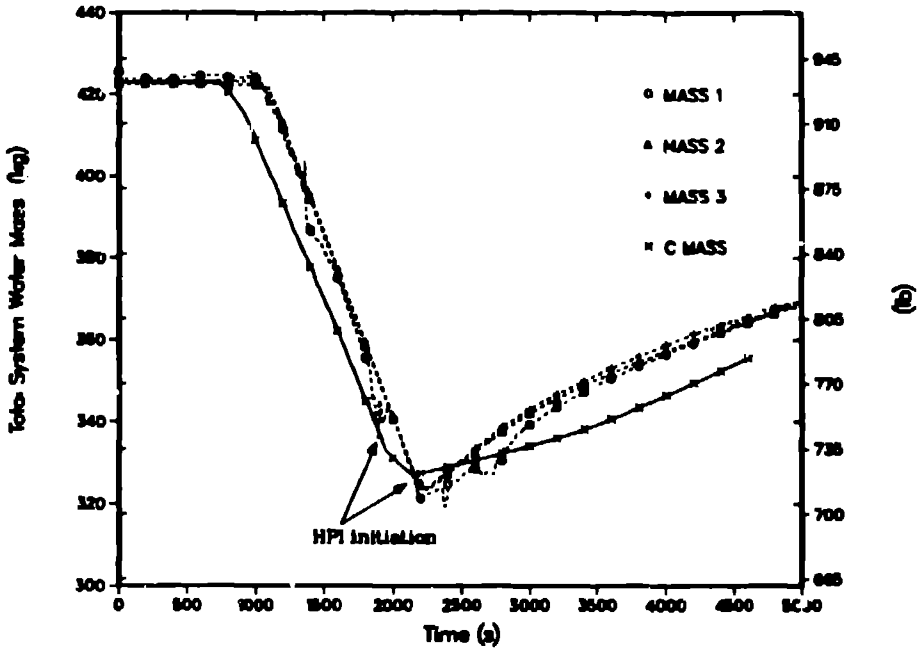

Fig. 4.i.
MIST Test 330302 primary-side water mass.

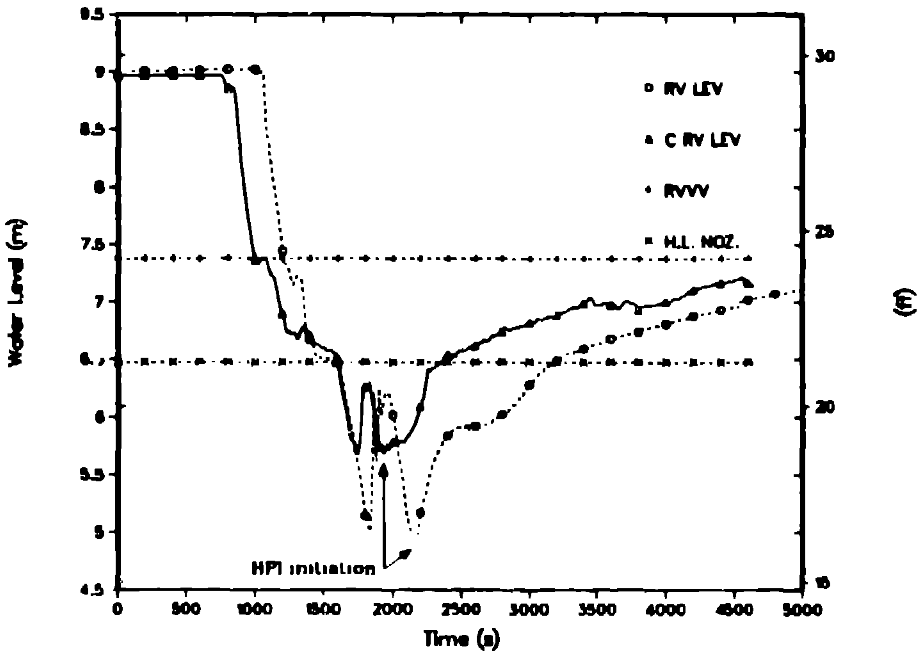

Fig. 4.j.
MIST Test 330302 reactor vessel collapsed liquid level.

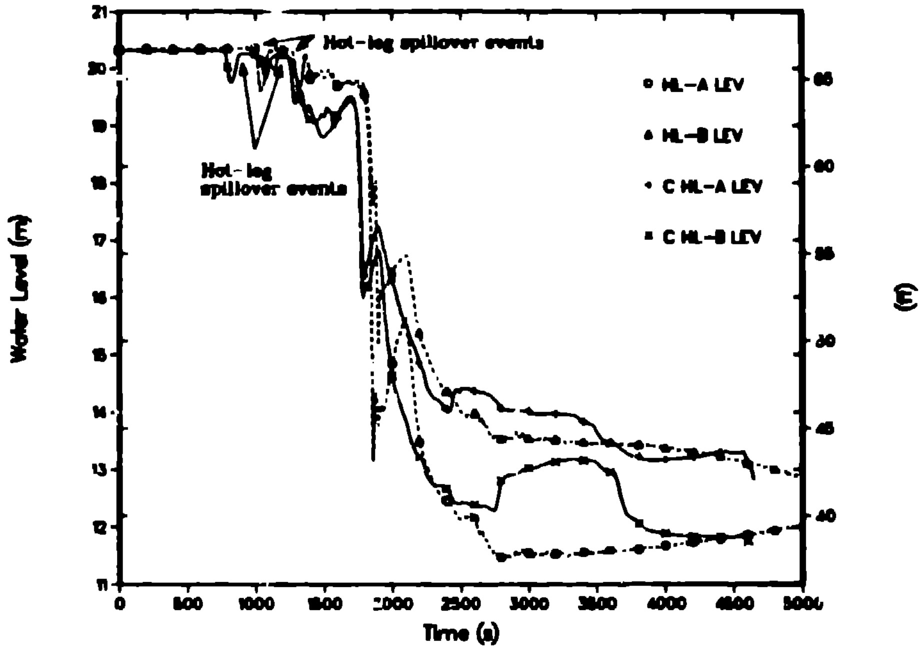

Fig. 4.k.
MIST Test 330302 hot-leg collapsed liquid level.

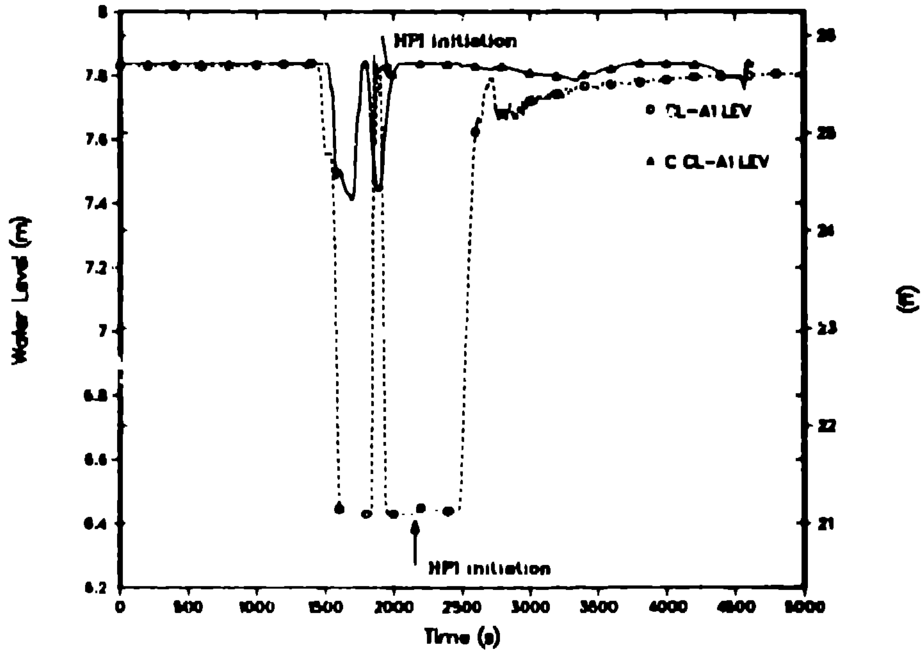

Fig. 4.l.
MIST Test 330302 Loop A1 cold leg collapsed liquid level.

TABLE I

EVENT TABLE FOR TEST 330302

Test Time (s)	Calculation Time (s)	Event Description
0.0	0.0	Start transient – loss of AFW to SG secondaries.
942.0	730.0	Primary system pressure increases to 16.20 MPa (2350 psia) and PORV lifted. PORV maintained open for remainder of test.
942.0	730.0	Core power decay ramp initiated.
1025.0	860.0	RVVVs first close.
1080.0	935.0	Pressurizer full.
1680.0		SG secondary isolated
2142.0	1930.0	HPI started
	4560.0	Calculation terminated (vessel refilled to near RVVV level).

and heatup phenomena were calculated, but the pressurization was more rapid than measured and the PORV set point was reached at 730 s. We believe that this discrepancy is related to our modeling of the pressurizer and surge line, specifically to the initial fluid temperature distributions in the surge line and pressurizer and the pressurizer noding. During this period the pressurizer liquid level was increasing as a result of primary-system swelling as shown in Fig. 4.b. The calculated rate of steam generation in the SG secondary during the boiloff was greater than measured as shown in Fig. 4.e. Thus, TRAC seemed to predict excessive heat transfer to the SG secondary during the SG-boiloff period. Primary-system mass flows were provided for the reactor-vessel vent valves (RVVVs), Loop-A1 cold leg, and downcomer in Figs. 4.f through 4.h. The early RVVV flow was underpredicted. The predicted loop and downcomer flows displayed the same trends as seen in the test but the magnitude of flow swings was underpredicted. The period from test initiation to PORV actuation was designated as Phase 1, SG dryout period.

Phase 2 of the transient covers the period between PORV actuation and HPI initiation 1200 s later. This period was a time of primary system inventory depletion and covers the time between 942 and 2142 s in the test. The corresponding calculated times were 730 and 1930 s. Boiling began in the hottest regions of the primary following PORV actuation as shown in Fig. 4.d. Boiling was predicted to occur earlier than measured because the PORV was opened earlier, as previously discussed. Immediately following PORV actuation, the pressurizer filling rate increased in both the calculation and test. Two-phase fluid was released through the PORV while the pressurizer filled and then liquid was released through the PORV. The PORV mass flow is shown in Fig. 4.c. Because HPI flow was delayed for 1200 s after PORV actuation and there was no other primary coolant makeup, primary system liquid levels began to decline. The reactor vessel collapsed liquid level is shown in Fig. 4.j. The calculated and measured level trends display a similar character but the observed liquid levels were lower. This was a direct result of the underprediction of PORV mass flow during Phase 2, as shown in Fig. 4.c. Calculated and measured hot and cold leg collapsed liquid levels are shown in Figs. 4.k and 4.l, respectively. In both the calculation and the test, voiding occurred in the hot legs first and was followed by several U-bend spillover events. The effect of the U-bend voiding and spillover events was observed in the Loop-A1 cold-leg and downcomer mass flows (see Figs. 4.g and 4.h). The Loop-A1 cold-leg mass flow stagnated following the hot-leg liquid spillover event that occurred in the test at approximately 1475 s and a similar stagnation was predicted, although it occurred slightly earlier. There was a subsequent short-lived hot-leg spillover event that occurred in the test at 1870 s and re-established flow in the Loop-A1 cold leg; this phenomenon was predicted. There was a marked difference between measured and calculated SG performance, as shown in Fig. 4.e. Dryout was predicted to occur at about 680 s while the SG was still steaming in the test when it was isolated at about 1600 s. We have determined that our initial specification of SG-secondary liquid level based on measured liquid levels was low. In addition, we have determined that the predicted primary-to-secondary heat transfer was too high.

Phase 3 of the transient covers the period between HPI initiation and about 4650 s, the end of the posttest assessment calculation. HPI was activated at 2142 s in the test. There were several direct consequences of the HPI activation. First, the primary-system pressure, which had slowly oscillated while generally trending upward during Phase 2, began to slowly decrease in both the test and the prediction, as shown in Fig 4.a. Second, the PORV flow rate abruptly decreased, as shown in Fig. 4.c, indicating that two-phase flow was established through the PORV. The pressurizer liquid levels provided in Fig. 4.b show that a small vapor space was established at the top of the pressurizer. First the reactor vessel and then the cold legs begin to refill, as shown in Figs. 4.j and 4.l, respectively. In each case, the major test trends were predicted. Finally, an intraloop cold-leg circulation began at about 2770 s, as shown in Fig. 4.g. The predicted start of intraloop circulation was about 1900 s later.

MIST Test 330302 displayed many phenomena of interest. These included an SG-secondary boiloff, slow primary-system pressurization at constant primary-system inventory, single- and two-phase fluid flows through the PORV, hot-leg spillover events, cold-leg and downcomer flow interruptions and the flow recovery, the effects of late HPI injection into a voided primary system, and primary-system refill. In general, the TRAC-calculated results are in reasonable agreement with the observed phenomena. Thus, TRAC-PF1/MOD1 provides an acceptable prediction of the test. All major trends and phenomena were correctly predicted. Two areas of concern observable in Figs. 4.a–4.l were identified. First, the calculated PORV flow rate is less than measured. Because the MIST system behaviors are very sensitive to primary system inventory, a more accurate prediction of the PORV flow rate is desirable. Second, TRAC predicted the too rapid transfer of heat from the primary to the SG secondaries during Phase 1, SG dryout. This resulted in the too rapid pressurization of the primary to the PORV setpoint.

Test 3404AA Transient Calculation.

The test was begun from steady state conditions meeting prescribed tolerances. A steady state calculation was run to 2000 s, corresponding to about five loop transits. At the end of the steady state calculation, the primary and secondary system fluid conditions had stabilized within the uncertainties of the measured values.

An overview of the test and calculated transients is presented in Figs. 5.a–5.l. Major events are summarized in Table II. SGTR transient 3404AA was initialized at time zero from the steady state by opening the valve in the SGTR line connecting the B-loop SG primary at the top of the SG to the top of the SG secondary. The tube rupture orifice represented a scaled 30.8 cm^2 double-ended break of 10 tubes at the top of the SG. After the primary-system subcooling dropped below 27.8 K (50°F), HPI was to have been initiated, the secondary fill of the A-SG was to have begun, AFW to the B-SG was to have been terminated, and a secondary cooldown of 55.6 K/hr (100°F/hr) was to have been initiated. These actions were taken late in the test but were still completed before the primary saturated. The test was judged acceptable as run.

An overview of the resultant test and calculated transients are shown in Figs. 5.a–5.l. With the opening of the SGTR, the subcooled primary system depressurized quickly (Fig. 5.a). The flow though the orifice was greater in the test than calculated by TRAC. The pressurizer emptied and the hot legs first saturated at about the same time, 70 s in the test and 80 s in the calculation. The hot-leg liquid level (Fig. 5.b) dropped quickly in the A-loop as inventory drained. The initial system voiding occurred in the A-loop because the liquid entering the A-loop from the pressurizer was warmer and flashed more readily. Natural-circulation flow interrupted in the A-loop at 80 s in the test and 120 s in the calculation (Fig. 5.c) as the hot-leg level dropped too low to allow spillover. The timing in the calculation was slower because the calculated flow rate through the SGTR orifice was smaller and calculated inventory greater.

The pattern seen in the B-loop flows (Fig. 5.d) was similar to the pattern seen in a number of other MIST Tests. The rate of depressurization slowed as voiding began in the upper head at 140 s in the test and 220 s in the calculation. B-loop natural-circulation flow increased to a peak at 190 s in the test and 270 s in the calculation and then declined rapidly as the liquid level fell away from the U-bend. Flow in the B-loop then ceased at 220 s in the test and 330 s in the calculation. Primary pressure (Fig. 5.a) reached a minimum at these times and started to increase. At 270 s in the test and 380 s in the calculation, the liquid level in the reactor vessel had drained to the RVVV elevation (Fig. 5.e). The downcomer contained cooler liquid than in the reactor vessel so that voiding was less extensive in the downcomer. The downcomer level did not drop as quickly. This exposed the ends of the RVVV lines in the reactor vessel to steam while the RVVVs were still below the liquid level in the downcomer. This condition caused the RVVVs (Fig. 5.f) to close. With the RVVVs closed, the voiding in the reactor vessel forced flow up the hot legs. This produced a spillover flow surge that peaked at 330 s in the test and 480 s in the calculation (Figs. 5.c and 5.d), and that ended at 360 and 580 s, respectively. Continued voiding, as inventory continued to drop rapidly, uncovered the RVVV elevation in the downcomer so that the RVVVs reopened allowing steam flow through them at 380 s in the test and 580 s in the calculation. This exposed steam from the core to cold HPI liquid draining down the cold legs into the downcomer, producing significant condensation and thus depressurization.

The repressurization that began at 220 s in the test and 330 s in the calculation ended at 290s and 470 s, respectively, because the increased flow through the broken hot leg provided sufficient cooling. After that time, the condensation on HPI and heat transfer to the SGs along with the inventory loss through the SGTR was sufficient to keep primary system depressurizing until the B SG was isolated. After about 400 s, the SGTR line on the primary side uncovered allowing steam or two phase flow out the break, increasing the volumetric flow rate while decreasing the rate of primary inventory loss

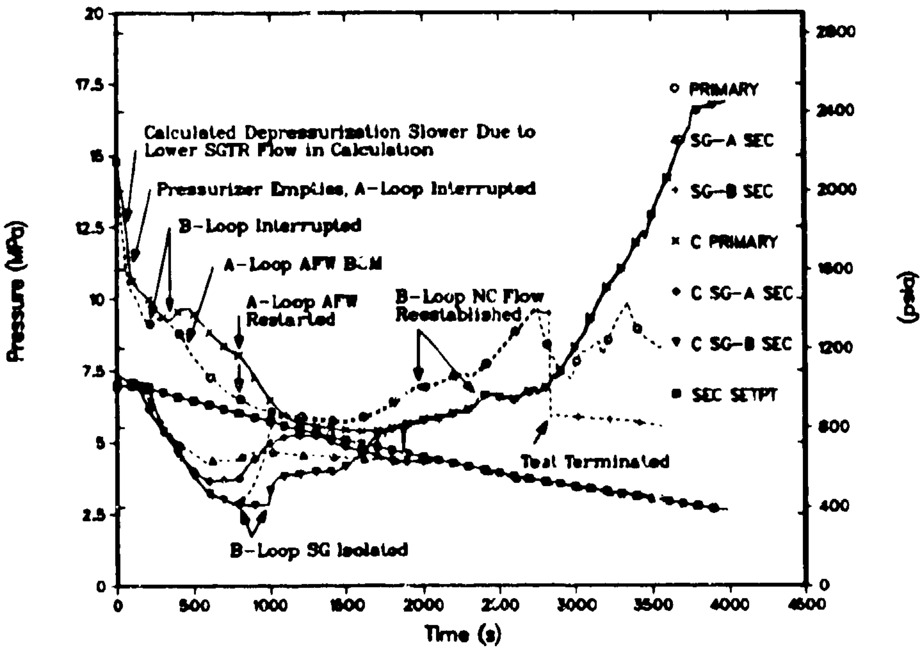

Fig. 5.a.

MIST Test 3404AA, primary and secondary pressures.

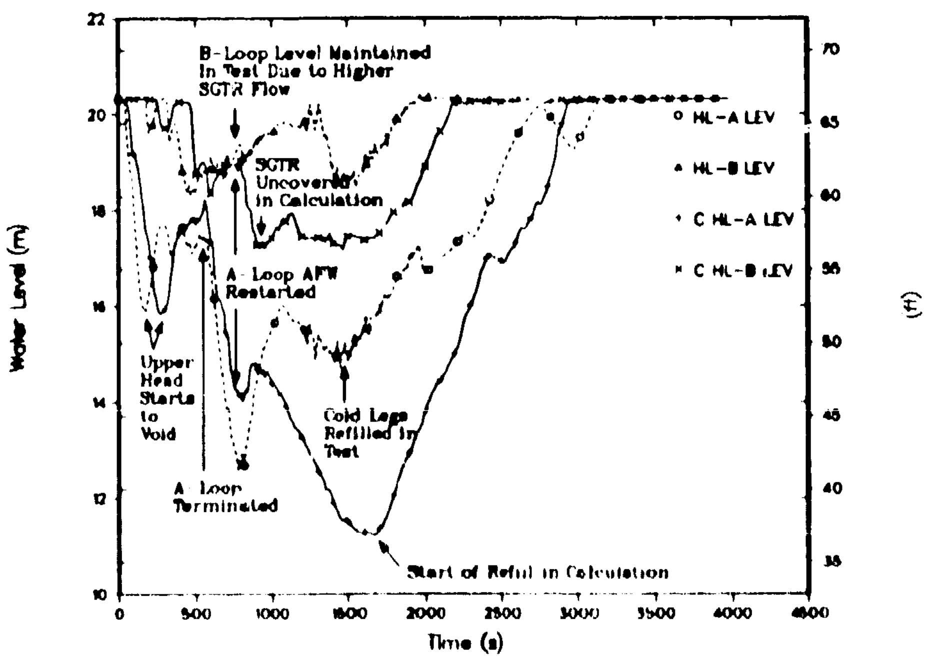

Fig. 5.b.

MIST Test 3404AA, hot leg collapsed liquid levels.

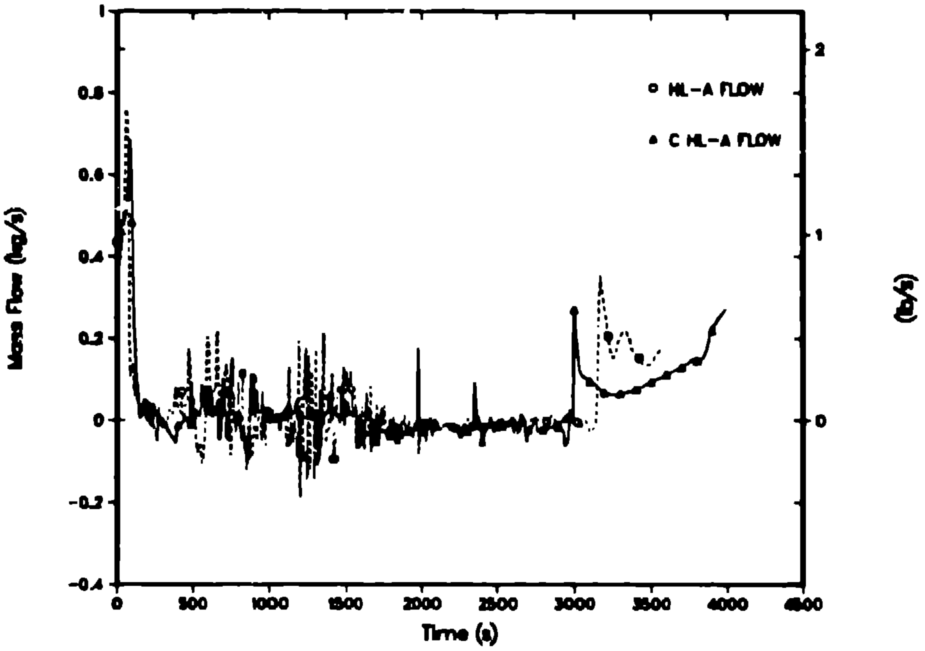

Fig. 5.c.

MIST Test 3404AA. SG-A primary mass flow.

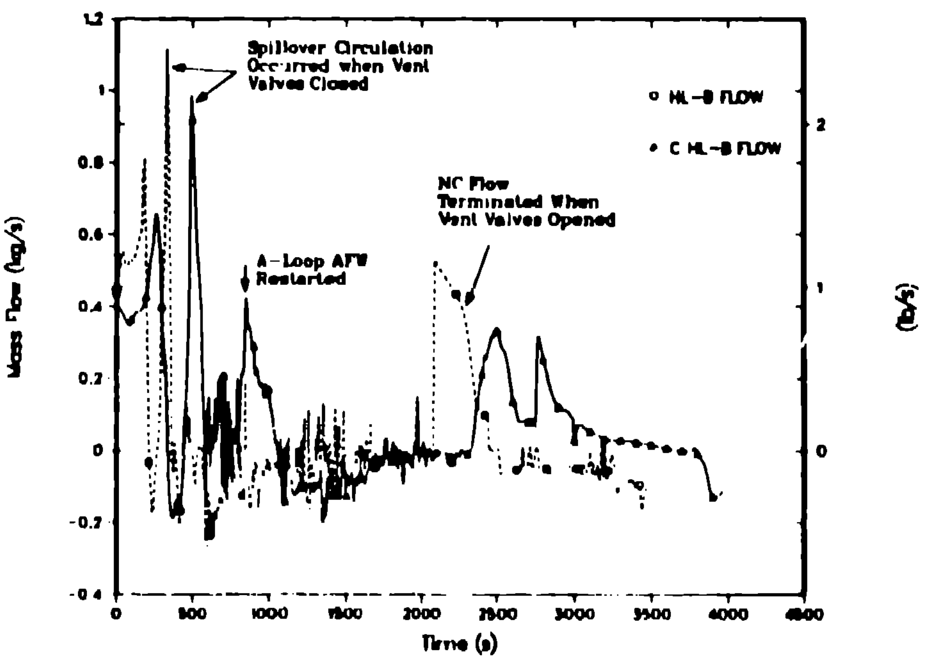

Fig. 5.d.

MIST Test 3404AA. SG B primary mass flow.

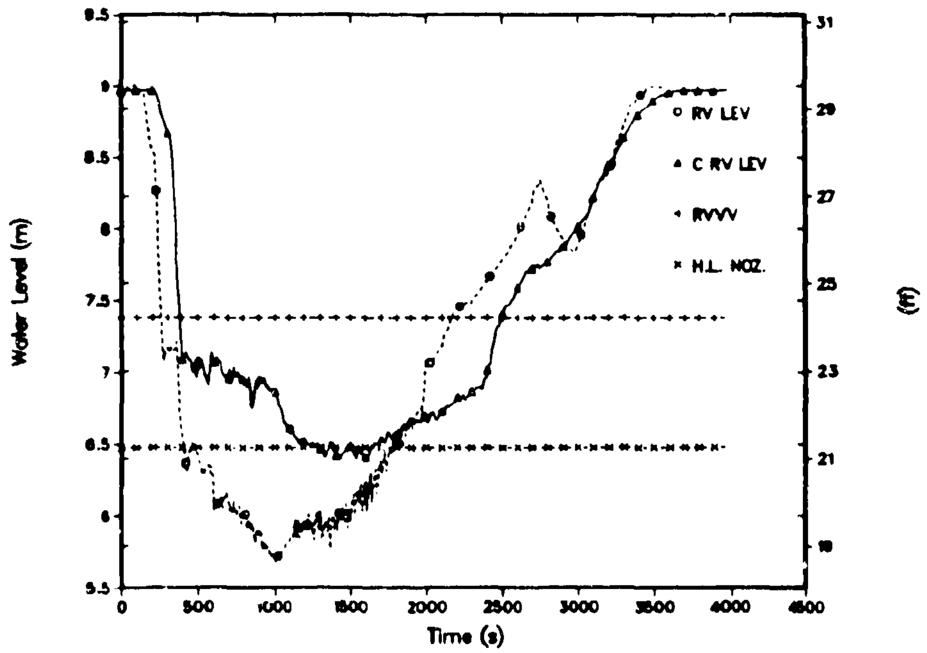

Fig. 5.e.
MIST Test 3404AA, reactor-vessel collapsed liquid level.

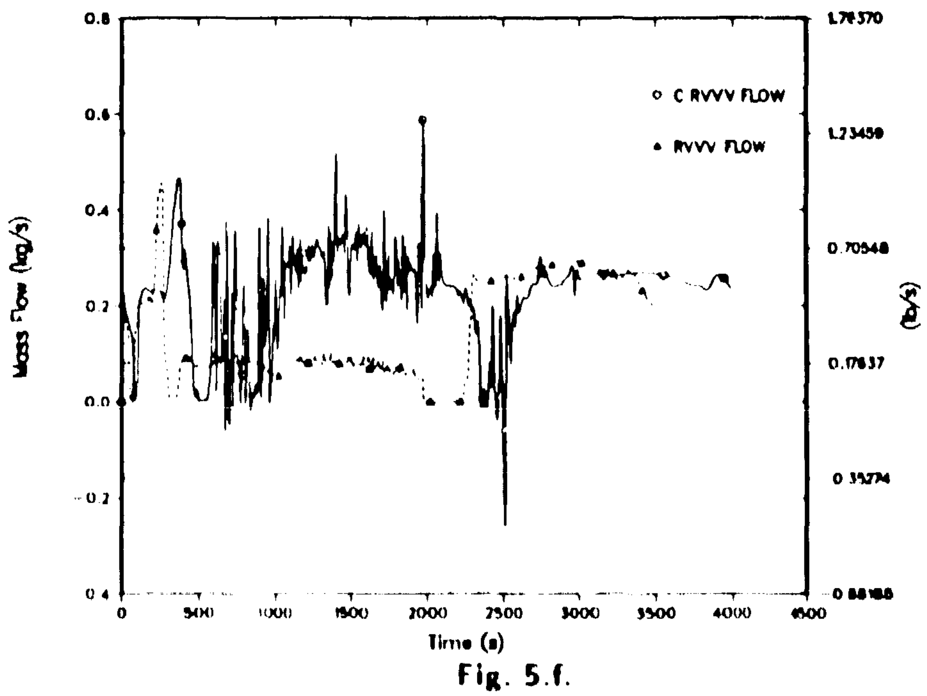

Fig. 5.f.
MIST Test 3404AA, RVVV mass flow.

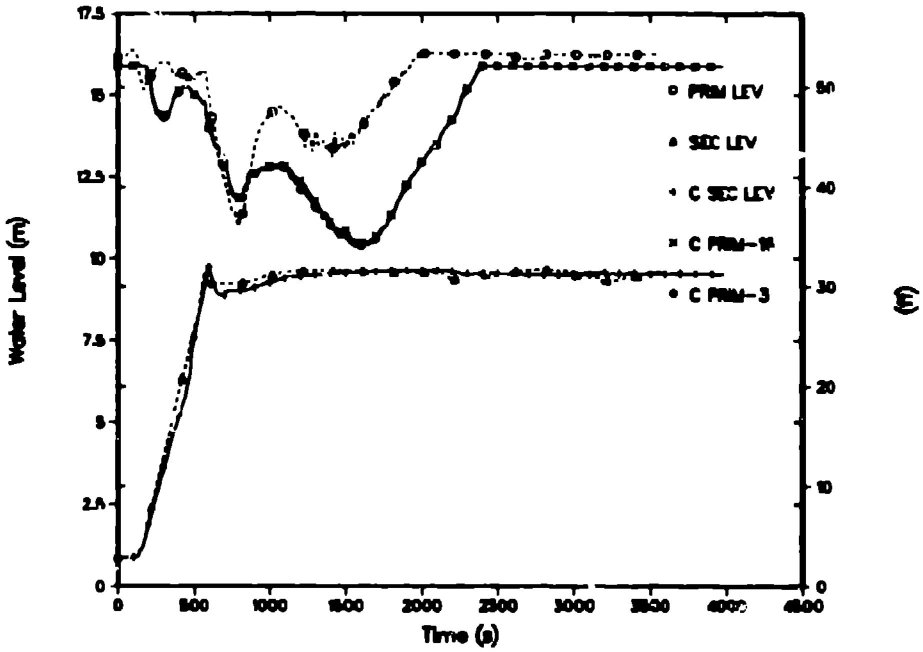

Fig. 5.g.
MIST Test 3404AA, SG-A collapsed liquid levels

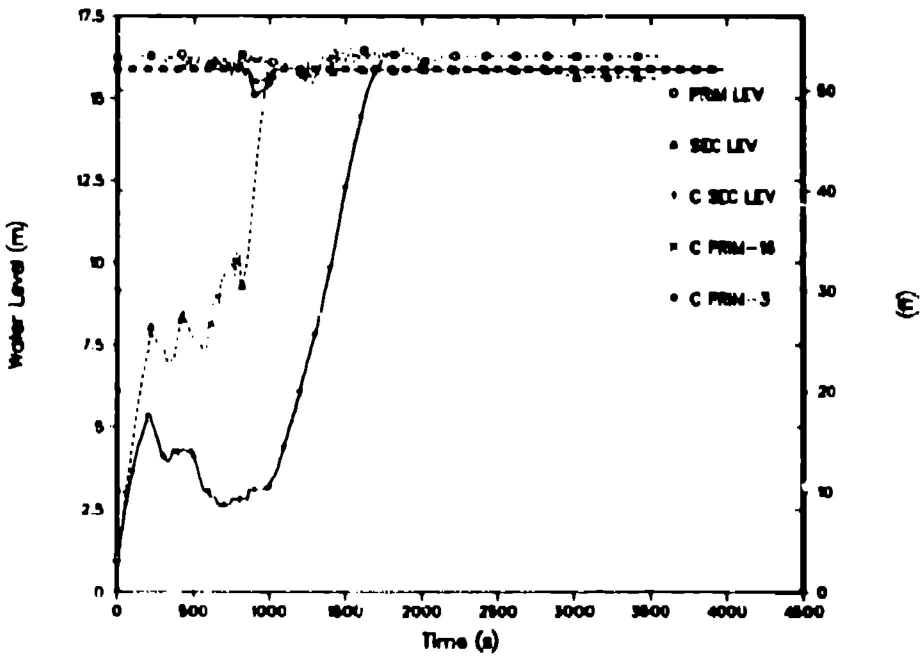

Fig. 5.h.
MIST Test 3404AA, SG B collapsed liquid levels.

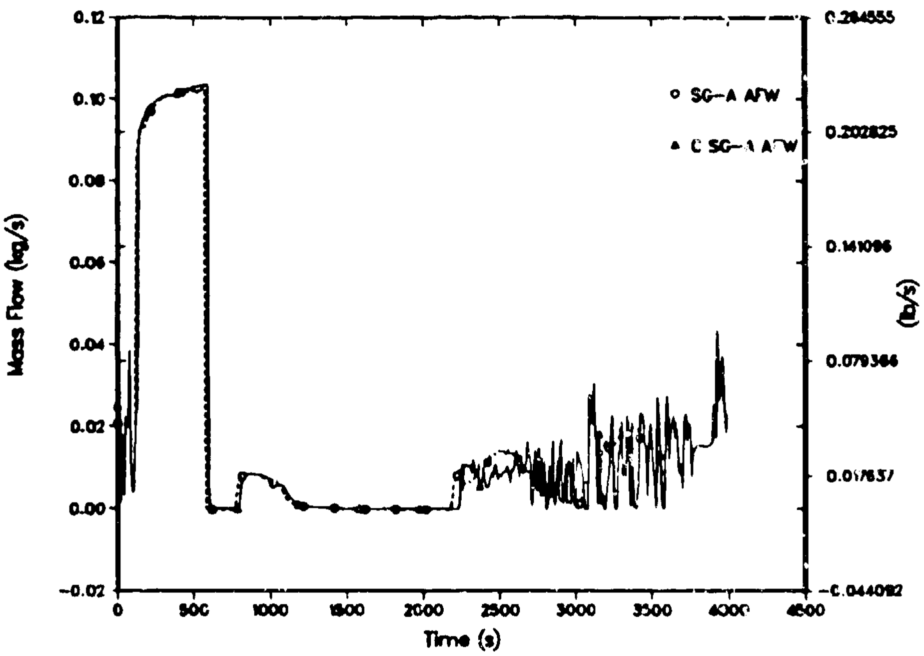

Fig. 5.i.
MIST Test 3404AA. SG-A AFW flow.

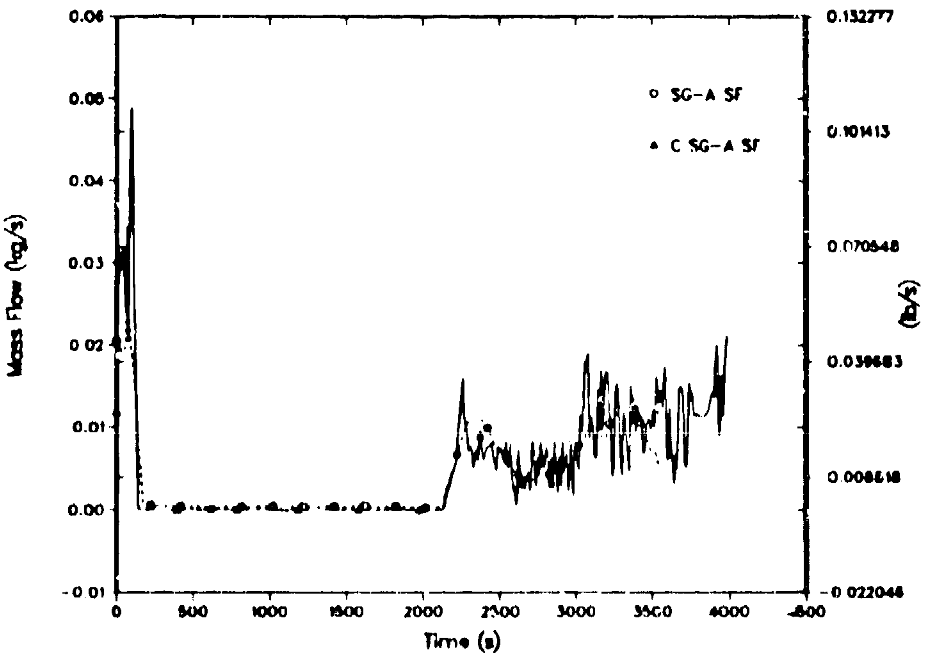

Fig. 5.j.
MIST Test 3404AA. SG A steam flow.

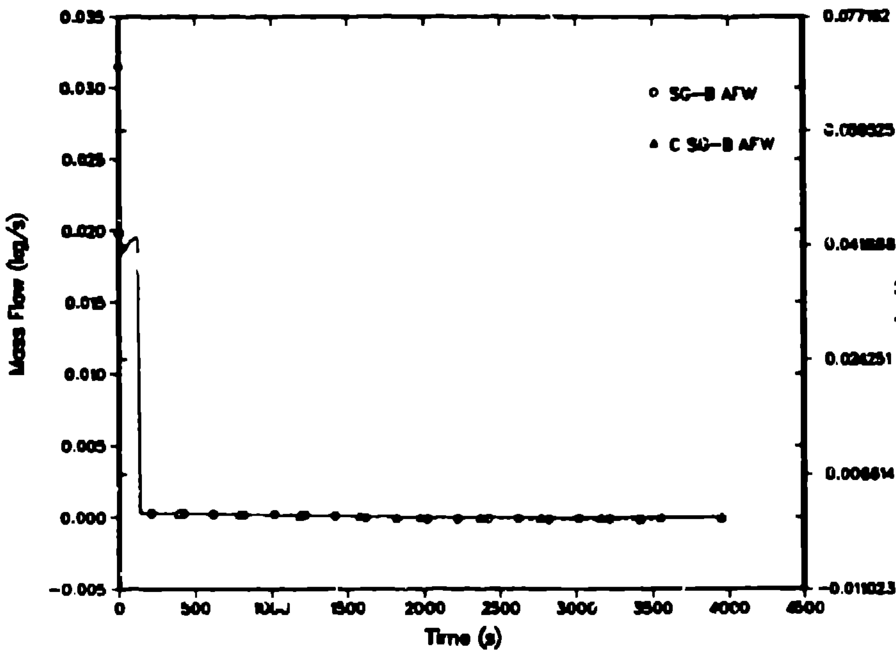

Fig. 5.k.
MIST Test 3404AA. SG-B AFW flow.

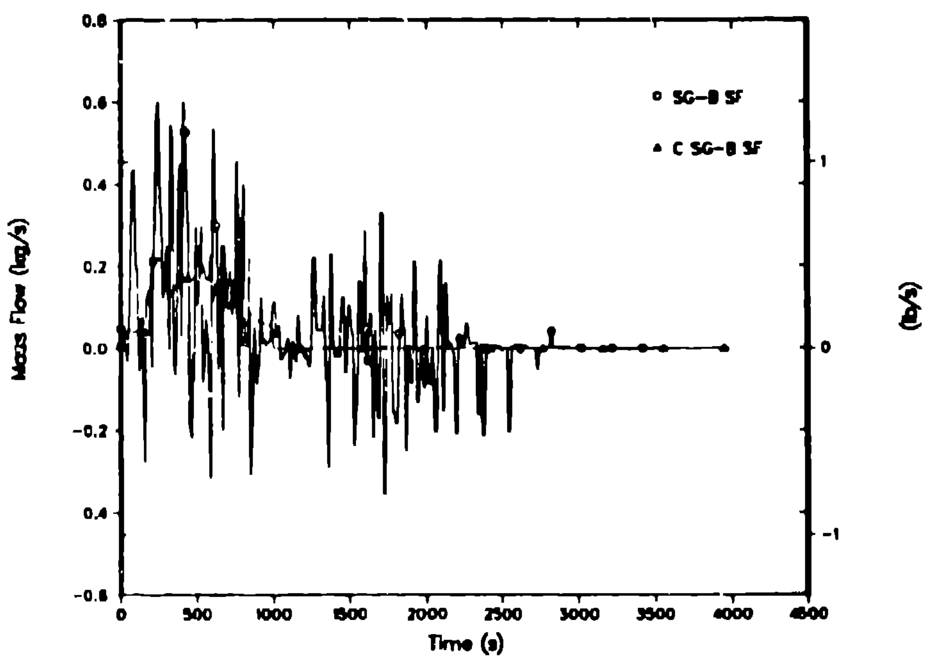

Fig. 5.l.
MIST Test 3404AA. SG B steam flow.

TABLE II

EVENT TABLE FOR TEST 3404AA

Test Time (s)	Calculation Time (s)	Event Description
0.0	0.0	Start transient – open SGTR valve.
70.0	80.0	Primary system saturates.
80.0	120.0	Natural circulation interrupts in A-loop.
360.0	480.0	Natural circulation interrupts in B-loop.
800.0	990.0	B-loop SG secondary isolated.
2700.0		Test aborted on maximum SG pressure.
	4560.0	Calculation terminated (vessel refilled to near RVVV level).

SG levels are given by Figs. 5.g and 5.h. AFW and steam flows for the SG secondaries are given by Figs. 5.i through 5.l. The B-loop SG provided a good heat sink for the natural-circulation flow ending at 360 s because steaming had been increased at about 200 s in the B-SG in response to the level increase caused by the SGTR flow (Figs. 5.h and 5.l). AFW boiler-condenser mode (BCM) heat transfer in the A-SG was also important for determining the depressurization rate. During the test, BCM occurred during refill from about 130 to 170 s and from 400 to 570 s. The corresponding times for the calculation were 200 to 350 s and 480 to 600 s. These were times when the level in the primary side of the A-SG (Fig. 5.g) was below the elevation of the AFW injection nozzle and AFW was on (Fig. 5.i). After the A-SG had refilled, AFW was off while control modes changed. Beginning at 770 s in the test and 800 s in the calculation, AFW came back on (Fig. 5.i) to maintain the level. This created AFW BCM in the A-SG from 770 to 1200 s when the AFW ended.

At 800 s in the test and 990 s in the calculation, the primary pressure (Fig. 5.a) dropped to 6.55 MPa (950 psi) and the B-SG was isolated. In the test, the B-SG then filled and the secondary pressure came to equilibrium with the primary by about 1000 s (Figs. 5.h and 5.a). In the calculation, the process was much slower because the initial level of the SG secondary was lower and because of the smaller leak flow rate. Equilibrium was not reached in the calculation until about 1700 s (Fig. 5.a).

The collapsed liquid level in the reactor vessel (Fig. 5.e) dropped below the hot-leg nozzle elevation at 490 s in the test and declined slowly until the B-SG was isolated and filled at 1000 s. In the calculation, the collapsed liquid level in the B SG never dropped below the hot-leg nozzle elevation. System inventory in the calculation began increasing when the isolated SG came to equilibrium with the primary, at about 1700 s.

After isolation of the B-SG, the primary pressure in the test stabilized and the primary began to refill. At 1500 s, the cold legs, which had voids in the vicinity of the RCPs, refilled. Cold legs in both loops went into an intraloop circulation where flow is in the forward direction for one cold leg of a pair and in the reverse direction in the other. This brought warmer water to the downcomer and decreased the condensation of steam. With no strong depressurization mechanisms operating, the primary began to repressurize (Fig. 5.a). In the calculation this was delayed until about 1800 s.

At about 1950 s in the test, the downcomer had filled to the RVVV elevation closing the RVVVs. Steam generation from the core then forced some flow through the B-loop (Fig. 5.d) into the isolated, B-SG. This provided a weak heat sink, which reduced the repressurization rate. This flow lasted about 200 s, the time for the liquid level in the reactor vessel to rise to the RVVV level, causing the RVVVs to reopen. In the calculation, the same events occurred about 400 s later.

At about 2200 s, the control signal for SG-secondary pressure decreased to the pressure of the A-SG, and steaming began to further reduce the A-SG pressure (Fig. 5.a). AFW then came on in the A-SG to maintain the secondary level. This event occurred at about the same time in both test and calculation. In the calculation, the primary level (Fig. 5.g) was still low enough to produce some BCM heat transfer and reduce the repressurization rate. In the test, refill had been under way for about 700 s longer, so the A-SG primary level was higher, too high for BCM heat transfer to occur.

The A-SG was not coupled to the primary in any strong way in the test during the period after 2200 s, when the A-SG was being cooled. Also, when the RVVVs reopened at 2300 s, the flow through them was liquid so the path for vapor to contact HPI liquid was no longer available. This eliminated the major mechanisms for depressurization and the primary repressurized (Fig. 5.a) at a faster rate after 2300 s.

The test was aborted at about 2700 s when the pressure of the primary and the B-SG reached the maximum pressure for the model SGs of the MIST facility. At the time the test was aborted, the primary had nearly refilled. B&W believed (Ref. 4) that natural-circulation flow would have begun shortly in the A-loop, allowing a one-loop cooldown. Had the pressure continued to rise, PORV-HPI cooling could also have been used. Both of these phenomena had been demonstrated in other MIST Tests. Most of the phenomena of interest for an SGTR with isolation of the damaged SG had occurred prior to the termination of the test.

The calculation showed the phenomena and trends of the test. The SGTR line had been geometrically modeled but showed lower calculated flows than observed in the data. This may indicate that TRAC could be improved for this situation. Data for the tube rupture flows in the test were derived from component inventory data. Thus, flow rates do not give good instantaneous values for making detailed comparisons.

CONCLUSIONS

Both Test 330302 and Test 3404AA showed many phenomena of interest. In both cases the overall level of agreement between test and calculation was judged to be reasonable; that is, that major trends are predicted correctly, although TRAC values are frequently outside the range of data uncertainty. We believe that correct conclusions will be reached if the code is used in similar applications despite minor code/model deficiencies.

Test 330302. Two areas were found where facility knowledge was inadequate. Transient data showed that the surge line and lower part of the pressurizer contained cold water at steady state. The few thermocouples in these components were located away from the low regions where this cold water was located and did not reveal its presence. The calculation was initialized with the pressurizer and surge line at the temperatures indicated by the thermocouples. The calculation shows considerable sensitivity to the pressurizer and surge-line conditions, and we believe that the differences in timing between test and calculation were caused, at least in part, by inaccuracies in the initialization of the pressurizer and surge-line conditions in the model. Facility data also seem inconsistent between the amount of liquid initially in the SGs, as indicated by liquid levels, and integrated steam flows through the steam line. This may have contributed to the earlier predicted boil-off of the SGs in the calculation.

One area was found where the TRAC model of the MIST facility was inadequate for this transient and was modified. The bottom cell of the SG secondaries was subdivided into five cells. This improved the calculation of the SG boil-off rate.

Two areas were identified where code models and correlations might be improved. The primary-to-secondary heat transfer in the SGs during phase 1 appeared to be overpredicted. This may indicate a need for refinement of the TRAC heat-transfer package. Also, the critical flow from the PORV appeared to have a different sensitivity to subcooling than predicted by TRAC for single-phase liquid flow. With the differences between the temperature profiles that apparently existed within the pressurizer and surge line, and the values used in the calculation, it is difficult to draw a definitive conclusion about the critical flow model sensitivity to subcooling.

Test 3404AA. The differences between the test data and the calculation for Test 3404AA can be attributed primarily to the difference between the SGTR flow in the test and the calculation. Even though we judge the overall agreement between test and calculation to be reasonable, that is, the calculation showed the same trends as the test, the time shifts were of sufficient magnitude to prevent the isolation of secondary causes of differences between test and calculation. The SGTR line was geometrically modeled. Flow losses because of acceleration of the fluid as it enters the tube, and/or frictional losses predicted for the high velocity through the small tube, are too large. This was also observed for a calculation of MIST Test 320201, a scaled 50-cm^2 small-break loss-of-coolant accident test. In both of these tests, the leak orifice was located in a tube branching off a much larger pipe and with much larger velocities than the pipe. This is apparently a code problem that can be alleviated to some extent with noding changes. It is a deficiency that makes the accurate prediction of flow through leak orifice tubes difficult. We believe that the effect on calculations with plant decks is not significant.

The code/data analyses presented herein constitute part of an assessment matrix for the performance of the TRAC-PF1/MOD1 code, which will ultimately be used to extrapolate data from the MIST facility to full-scale plant behavior.

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Appendix A

Code Assessment Descriptor Definitions

The descriptors will be used to provide an overall characterization of how TRAC predicted the thermal-hydraulic behavior in the MIST facility. Four descriptors are used to characterize the degree of agreement and the application consequences of either the agreement or lack of agreement. The four descriptors are **excellent agreement**, **reasonable agreement**, **minimal agreement**, and **insufficient agreement**. Each of these descriptions will be defined below along with the consequences for future application of the code in the given area being characterized and the perceived need for additional code development.

Excellent agreement is an appropriate descriptor when the code exhibits no deficiencies in modeling a given behavior. Major and minor phenomena and trends are correctly predicted. The calculated results are judged by the analyst to be close to the data with which a comparison is being made. If the uncertainty of the data has been identified and made available to the analyst, the calculation will, with few exceptions, lie within the uncertainty band of the data. The code may be used with confidence in similar applications. Neither code models nor the facility noding model require examination or change.

Reasonable agreement is an appropriate descriptor when the code exhibits deficiencies, but the deficiencies are minor; that is, the deficiencies are acceptable because the code provides an acceptable prediction of the test. All major trends and phenomena are correctly predicted. Differences between the test and calculated traces of parameters identified as important by the analyst are greater than those deemed necessary for excellent agreement. If uncertainty data are available, the calculation will frequently lie outside the uncertainty band. However, the analyst believes that the discrepancies are not sufficiently large to require a warning to potential users of the code in similar applications. The assessment analyst believes that the correct conclusions about trends and phenomena would be reached if the code were used in similar applications. The code models and/or facility noding model should be reviewed to see if improvements can be made.

Minimal agreement is an appropriate descriptor when the code exhibits deficiencies and the deficiencies are significant; that is, the deficiencies are such that the code provides a prediction of the test that is only conditionally acceptable. Some major trends or phenomena are not predicted correctly while others are predicted correctly. Some TRAC calculated values lie far outside the uncertainty band of the data with which a comparison is being made. The assessment analyst believes that incorrect conclusions about trends and phenomena may be reached if the code were used in similar applications. The analyst believes that certain code models and/or the facility noding model must be reviewed, corrections made, and a limited assessment of the revised code or input models made before the code can be used with confidence for similar applications. A warning should be issued to the TRAC user community that the user applying the code in similar applications risks drawing incorrect conclusions. This warning should stay in force until the identified review, modification, and limited assessment activities are completed and the resultant characterization descriptor is "reasonable" or better.

Insufficient agreement is an appropriate descriptor when the code exhibits major deficiencies; that is, the deficiencies are such that the code provides a prediction of the test that is unacceptable. Major trends are not predicted correctly. Most TRAC calculated values lie far outside the uncertainty band of the data with which a comparison is being made. The assessment analyst believes that incorrect conclusions about trends and phenomena are probable if the code is used in similar applications. The analyst believes that certain code models and/or the facility noding model must be reviewed, corrections made, and a limited assessment of the revised code or facility noding model made before the code can be used with confidence for similar applications. A warning should be issued to the TRAC user community that the code must not be used for similar applications until the identified review, modification, and limited assessment activities are completed and the resultant characterization descriptor is "reasonable" or better.